National Concrete Pavement Technology Center

Using Artificial Neural Networks in Pavement Structural Analysis

tech transfer summary

Developing artificial neural networks as a pavement methodology can improve the speed and efficiency of pavement layer evaluation.

Objective

The objective for this project was to develop an easy-to-use pavement methodology to evaluate existing structural conditions of pavements, with artificial neural networks (ANNs), that will use and interpret routinely collected nondestructive test data for rapid and accurate predictions of pavement layer parameters.

Problem Statement

Current pavement layer backcalculation techniques are cumbersome and more efficient and faster methods are now needed. The last decade has seen increased interest in a new class of computational intelligence systems, known as ANNs, for rapid and accurate predictions of layer parameters. Transportation departments are interested in the development of rapid models of backcalculating for pavement structural properties, including the use of ANNs.

Research Description

The backcalculation models proposed in this research were developed using a neural networks methodology. A suite of ANN-based models were selected for their adaptability and ease of use for backcalculation purposes. Type-specific models were developed for three broad pavement categories: flexible (conventional and full-depth), rigid, and composite. For each pavement type, state-of-the-art pavement structural modeling concepts were combined with ANN methodology to produce a robust pavement evaluation tool.

Bottom view of a FWD with sensor locations

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RESEARCH PROJECT TITLE
Nondestructive Evaluation of Iowa Pavements - Phase I

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In this study, the pavement layer stiffness properties and critical pavement responses were predicted from falling weight deflectometer (FWD) test results. For the three pavement types, over 300 models total were developed for varying input parameters.

All developed and ANN-based pavement structural models were compared with the existing and commonly used commercial software packages in the market. The ANN models were then validated using actual field data from selected sites in Iowa. The coefficient of determination value and average absolute errors AAE were also used to assess the quality of predictions.

Key Findings

The findings of this research focus on the issues involved with using ANN-based models for pavement layer analysis.

- ANNs demonstrated a capability in successfully predicting the pavement layer moduli values using the FWD field deflection measurements. Field moduli values were successfully predicted for the given deflection basins and comparison of the ANN-based predictions showed the strength of the ANN-based backcalculation approach.
- The ANN-based backcalculation models successfully predicted pavement layer moduli values (except for the base/subbase layer in flexible pavements) with an overall absolute average error value of less than 1.5 percent.
- The adoption of an ANN-based approach resulted in a drastic reduction in computation time and a simplification of the backcalculation approach from the viewpoint of a pavement designer/analyst.
- The rapid prediction ability of the ANN models, capable of analyzing 100,000 FWD deflection profiles in less than a second, provide a tremendous advantage to the pavement engineers by allowing them to nondestructively assess the condition of the transportation infrastructure system in real time.
- Elimination of the seed layer moduli selection step, combined with the integration of ANN-based direct backcalculation approach, can be invaluable for the state and federal agencies for rapidly analyzing a large number of pavement deflection basins needed for routine pavement evaluation for both project-specific and network-level FWD testing.

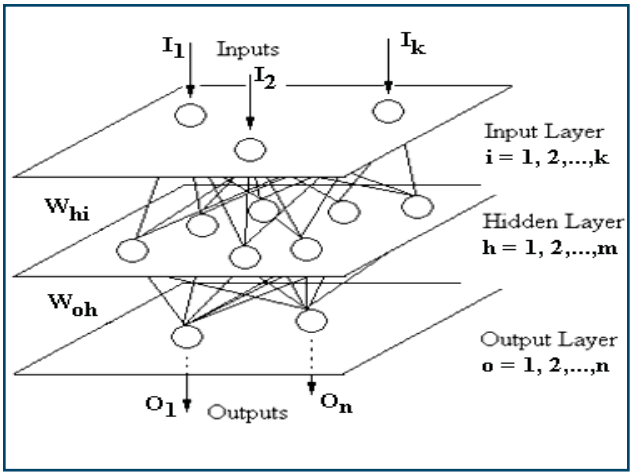
Recommendations

Although advanced approaches to pavement layer backcalculation have been developed in this study, the accuracy of results will largely depend on the quality and integrity of FWD deflection data collected in the field.

For this reason, future research efforts should focus on developing guidelines for the Iowa DOT that clearly define the FWD testing requirements, data analysis approach, and reporting requirements.

Both the current research and past research studies have shown that to successfully backcalculate the pavement layer stiffness, or to predict the critical pavement responses (maximum stresses, strains and deflections), accurate layer thickness information is needed, especially at the FWD testing points.

For this reason, future research efforts should focus on conducting sensitivity studies to determine the effect of pavement layer thickness on pavement performance data using the mechanistic-empirical based pavement design concepts.



A general view of an artificial neural network